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THE ULTIMATE SEASONAL INFECTION OF MALARIAL FEVER, WITH THE MOSQUITO CARRIER AS THE INDICATOR.

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It has been considered practicable to develop a sanitary indicator for malaria prophylaxis in the determination of the initial and terminal infection found existing among mosquitoes collected in districts where malarial fever thrives. The mosquito as an indicator was first suggested in a paper in which the following point was advanced: "It seems quite feasible to establish for any endemic focus what may be termed the malarial indicator. This is the determination of the time of the year when mosquitoes first acquire malarial infection. Thus, a fairly stable indicator may be obtained of the time when there is danger of the communicability of malaria from man to man. It might be entirely feasible to utilize the mosquito indicator to determine when active means of prophylaxis should be inaugurated in any locality, and, if necessary, likewise to determine at the end of the season when prophylaxis may be safely dispensed with." [1]

The present paper is an attempt to contribute some information pertaining to ultimate infection. The question of the date of the last occurrence of mosquito infectivity for the season must be considered purely from a local standpoint. Biologically regarded, the determination is applicable only to a district presenting conditions identical in meteorology and physiography to those of the district investigated. The matter is entirely concerned with mosquito and protozoan seasonal inactivity, coupled with malaria latency in the human host. This, of course, involves the temperature at the time when conditions are favorable for the onset of hibernation.

It is at once apparent that in addition to the collecting and examining of large numbers of mosquitoes in a malaria focus, it is just as essential to correlate data secured from blood examinations. In two districts investigated, careful history indexes were made in order to rule out any complication of fresh infection. Clinical cases of malaria were carefully reviewed, and in the majority of instances it could be fairly concluded that relapses were the rule. This conclusion was reached by analyzing the therapeutic measures taken in the individual case, and, in the presence of gametocytes in the blood at the time of a fresh paroxysm, verified by the history of previous infection.

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[1] Anopheles as a Winter Carrier of Plasmodium. By M. Bruin Mitzmain (Bruce Mayne). Reprint No. 290 from Public Health Reports, vol. 30, No. 29, July 16, 1915.

At the first place studied, Talladega Springs, Ala., 200 persons were examined during September, 1916, giving a malaria index of 18.6 per cent. Beginning September 17, anophelines were captured in habitations which were known to harbor cases of malarial fever. A total of 1,377 specimens of *Anopheles quadrimaculatus* and *A. punctipennis* were collected, and of these, 709 specimens were found suitable for dissection and examination.

Infected mosquitoes appeared on September 21, September 29, and finally, November 15. The last specimen, *A. quadrimaculatus*, was collected on November 1 from a plantation house where at least two persons proved to be gametocyte carriers. The mosquito was one of a lot which were held at room temperature for an additional two weeks to permit of maximum development of any parasites present. The only evidence of infection observable in this specimen was the appearance on the stomach wall of a single half-grown oocyst. In character, of stunted development (size 35–40 m.), the parasite showed no promise of development beyond the presporoblastic stage, giving evidence that the host had been exposed to temperature too low to permit of growth to maturity.

In the following table are given the weather conditions in temperature records (Fahrenheit) at weekly intervals, covering the time of the investigation at Talladega Springs, Ala., from September 1 to November 30, 1916:

Month.	First week.		Second week.		Third week.		Fourth week.		Fifth week.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
September	94	65	93	56	85	50	90	54	73	46
Mean	92	67	87	66	80	56	87	60	72	50
October	85	48	87	45	87	35	77	29	78	48
Mean	81	45	73	52	74	54	72	38	75	52
November	78	39	78	40	64	20	64	23	60	44
Mean	75	42	72	47	56	28	58	38	54	52

Monthly rainfall, in inches: September, 5.12; October, 0.88; November, 3.58.

In an investigation at Lenwil, La., during August to December, 1917, a preliminary survey among 250 lumber-mill villagers revealed a history index of 83 per cent, and a parasite index of 22 per cent. Here infected mosquitoes were captured beginning August 27 and ending November 1. A total of 746 anopheline mosquitoes of 3 species were dissected, of which 18 proved to be infected, as follows: Seventeen specimens of *Anopheles quadrimaculatus*, and one specimen of *A. crucians*. The last infected mosquitoes were captured on October 20 and November 1, the two specimens being *A. quadri-*

maculatus. In the one captured on October 20 the salivary glands revealed a moderate number of viable sporozoites in four salivary lobes, while the gut wall had a normal appearance. In the other specimen the stomach showed only a single oocyst, with no other evidence of parasitism. The oocyst appeared nonviable, with no evidence of sporoblast formation, and it probably would not have survived to maturity or infectibility. It appeared similar to forms seen in experimental infections wherein mosquitoes are exposed to low temperature for two weeks or longer.

In this section of Louisiana frost was first observed October 9 and again October 22. Between these dates infected mosquitoes were found as follows: Two on October 11, one October 13, and finally one on October 20. It must be noted that the biological conditions generally considered normal for parasitism continued in this region until the last week in November. Biological relations were not interrupted by seasonal modifications, for biting by anopheline mosquitoes was experienced and reported up to November 9; male mosquitoes still abounded, and evidences of true hibernation were not manifest until November 23.

Temperature records (Fahrenheit) of this district for the months of August to November, 1917, the period of the investigation, are given in the following table:

Month.	First week.		Second week.		Third week.		Fourth week.		Fifth week.		Mean.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
August	97	70	100	66	100	71	98	62	90	64	92	70
September	93	70	96	52	88	55	91	56	87	54	86	63
October	94	47	84	37	90	32	85	32	74	29	76	44
November	78	35	79	37	78	31	73	26	68	50	67	38

Monthly rainfall, in inches: August, 5.4; September, 3.39; October, 2.1; November, 1.52.

Discussion and Summary.

Protection against malarial fever through prophylactic means, afforded by a knowledge of the presence of infective organisms in the mosquito, is a measure placed at the disposal of the sanitarian. This is offered through biological research, using the insect host as an indicator.

There is a date (differing for place and year) up to which time mosquitoes are infective and beyond which time they are not. After this date malaria is not contracted by man. In Lenwil, La., this date should have been between October 20 and November 1 for the year 1917. On October 20 of that year an Anopheles was found with active viable sporozoites in her salivary glands, hence was presumably infective to man. After this date none with viable parasites was found, and the one dissected November 1 showed only a single half-ripe oocyst, arrested in development prior to the formation of sporozoites.

Until more complete data is obtained, it is assumed justifiable to give November 1 as the date of terminal infection in mosquitoes collected in northern Louisiana, at least for the year 1917.

This date is given with the necessary reservation and condition that it does not apply elsewhere at similar latitudes nor in the same localities for the following years. For absolute accuracy, in a biological sense at least, this determination must be repeated in the same locality and in different localities in the malarial zone from year to year.

In this connection it is interesting to note that in two regions of nearly the same latitude (about 33° north), but in different States, conditions practically identical were observed relative to the appearance and disappearance of anopheline infection. However, no great significance can be attached to this coincidence; and until many more malarial zones are given similar study, the faunal conditions bearing on malaria epidemiology, however interdependent, will have to be considered individually.

A knowledge of terminal infection with the mosquito as an indicator has considerable sanitary value, and it can be applied in a practical way by using it as a guide in deciding on the discontinuance of sanitary protection at a time when the mosquito no longer plays a pathological rôle. It furnishes the basis for the determination, in a selected zone, of a time when it is safe to curtail sanitary-control measures. Thus, needless expenditure of public funds may be averted in cases where such funds are limited to malaria control—where it is not the purpose to eradicate the mosquito merely as a pest. Applied practically, this indicator would operate in this manner: Assuming that November 1 was the date determined as that of ultimate mosquito infectibility, and it was desired to recommend the safe time at which to discontinue oiling or other larvicidal measures, allow 18 days for complete transformation from the larval stage, and 12 days for the adult mosquito to become infective,[1] a total of 30 days to be counted back from the date of ultimate infectibility. The date to be named for the safe discontinuance of operations against the mosquito as an infecting agency would then be October 1.

Concerning the question of personal quinine prophylaxis as influenced by a possible indicator of terminal infection, the writer is not prepared to make specific recommendations. The solution of this problem would be of considerable importance in highly malarious districts, especially in swampy areas, where screening and prophylactic dosage with quinine are solely depended on for malaria protection.

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[1] This is less time than would be required with the temperature near the point of preventing the development of the parasite in the mosquito.